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Regional Ozone Modeling in the Northeastern U.S. Selection of Meteorological Episodes

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16. ABSTRACT

In 1987, scientists and officials from the states and EPA regions in the Northeastern U.S. began a study of the photochemical smog problem along the Northeast Corridor. This study, called Regional Ozone Modeling for Northeast Transport (ROMNET), has three major components: (1) to identify emission control strategies, (2) to assemble emission inventories suitable for regional ozone modeling, and (3) to model the control strategies with appropriate meteorological and emissions data. One important prerequisite for the third component is to select meteorological episodes that reflect typical transport patterns associated with high ozone levels in the Northeastern U.S. The selection of three episodes was based on an objective air quality analysis and the frequency of days containing priority flow conditions. These flow regimes were along-corridor flow, recirculation, and westerly flow into the corridor. The following three episodes were selected and are proposed for modeling with the Regional Oxidant Model (ROM): (1) July 12-23, 1980, (2) June 9-20, 1983, and (3) June 4-13, 1984.

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REGIONAL OZONE MODELING IN THE NORTHEASTERN U.S.: SELECTION OF METEOROLOGICAL EPISODES

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1. INTRODUCTION

During the summer of 1988, the Northeastern U.S. not only suffered hot and dry weather but experienced high levels of photochemical smog. The extent of photochemical smog, a major component of which is ozone, is not limited to the Northeastern U.S. Despite efforts to control smog-producing pollutants, ozone values exceeding the National Ambient Air Quality Standard persist in Southern California, Houston, Chicago, and in many other major urban areas around the country (U.S. EPA, 1988).

To better understand regional transport, diffusion, and chemical transformation of ozone and its precursors, the United States Environmental Protection Agency (EPA) began field experiments (Vaughan, 1985) and model development activities in the late 1970's. As a part of this effort, Lamb (1983) has guided the Regional Oxidant Model (ROM) to a stage where it is now suitable for application. ROM is a three-dimensional Eulerian model with a grid resolution of ~18.5 km and a modeling domain of 1000 km by 1000 km. It is intended for simulation of hourly ozone concentrations associated with multi-day regional photochemical smog episodes. The processes that ROM can handle include horizontal and vertical advection, biogenic and anthropogenic emissions and their chemical reactions (Whitten and Gery, 1986), nocturnal jets, cumulus cloud effects, and mesoscale motions induced by large-scale synoptic flows and terrain.

With this new tool for examining the regional transport of ozone and with the realization that photochemical smog is a regional-scale problem, scientists and officials from the states and EPA regions in the Northeastern U.S. gathered in late 1987 to begin a modeling study of the ozone problem along the Northeast Corridor. This study, called Regional Ozone Modeling for Northeast Transport (ROMNET), has three major components: (1) identifying emission control strategies for reducing regional ozone levels, (2) assembling emission inventories suitable for regional ozone modeling, and (3) modeling the control strategies using appropriate meteorological and emissions data. One important prerequisite for the third component is to select meteorological conditions that reflect typical transport patterns associated with high ozone levels throughout the Northeast U.S. This paper discusses the procedures which were used for selecting the meteorological episodes.

* On assignment from Department of Commerce, National Oceanic and Atmospheric Administration.

2. RATIONALE AND PROCEDURE

The ROM simulations for ROMNET will be used to investigate the impact of alternative emission control strategies in the Northeastern U.S. Specifically, ROM will be used to assess the impact of the strategies on (1) boundary conditions for use in urban-scale modeling, (2) regional ozone concentrations, and (3) inter-urban transport.

Because of computer timing and manpower restraints in ROMNET, the number of episodes must be limited to about three, totalling approximately 30 days. Therefore, careful thought must go into selecting these episodes so that they reflect a full picture of the effects of various control strategies for meteorological conditions of interest. It was decided to select episodes from 1983 through 1987 - roughly the period surrounding the base case year, 1985. In addition, two 1980 episodes (July 12-23 and July 29 - August 9) were considered in the event that meteorological conditions of interest were not represented in the episodes from 1983 to 1987.

A two step process was used for selecting these episodes. First, ozone measurements were examined to identify periods of high ozone in the Northeastern U.S. Each episode was analyzed in detail and ranked according to its severity. Second, meteorological conditions were examined for the top ten episodes with the objective of selecting three episodes experiencing a variety of flow and synoptic regimes associated with high ozone observations in the Northeast Corridor.

3. AIR QUALITY ANALYSIS

The first step in the air quality analysis was to identify candidate episodes from ambient ozone measurements taken in 1980 and 1983-1987. Data for the analysis were available from EPA's Storage and Retrieval of Aerometric Data (SAROAD) and Aerometric Information Retrieval (AIRS) systems. Figure 1 shows the maximum hourly ozone concentration reported on a daily basis among the approximately 200 monitoring stations as well as the percentage of sites reporting an hourly concentration above 0.12 ppm. Because of space limitations, data only from 1980, 1983, and 1984 are shown in Figure 1. From an initial review of the data, 21 candidate episodes were selected as listed in Table 1.

The next step in the analysis was to rank the 21 episodes using an objective ranking scheme in which the magnitude, spatial coverage, and duration of high concentrations were considered. To ensure that the entire Northeast Corridor was included in the ranking of the episodes, the area was divided into three subregions: (1) Greater Boston (including southern Maine), (2) Greater New York (including portions of southern New England), and (3) Washington - Baltimore - Philadelphia (including southeastern Pennsylvania, southern NJ, and Delaware).

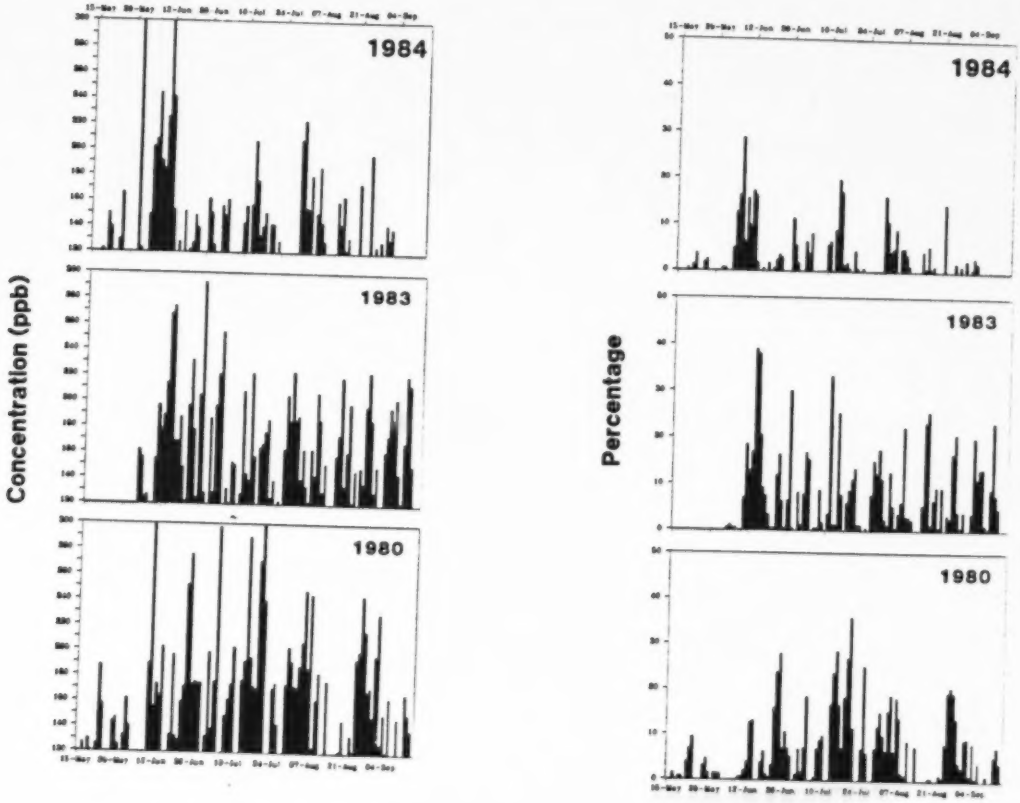

Fig. 1. Daily ozone statistics on measurements from the Northeast U.S. Maximum hourly concentrations are shown in the left-hand column; the percentage of measuring sites exceeding an hourly concentration of 0.12 ppm is shown in the right-hand column.

Episodes were then ranked according to the scores determined with the following equation:

$$TS_j = \sum_{i=1}^{3} Mag_i + \sum_{i=1}^{3} Dur_i$$

where TS_j is the total score for episode j, i is the subregion in the Northeast Corridor, "Mag" is the relative rank based on the number of stations reporting a maximum daily concentration greater than 0.15 ppm, and "Dur" is the relative rank based on the number of days with concentrations above 0.12 ppm anywhere in a subregion. Scores and corresponding ranks based on this analysis are shown in Table 1.

Table 1. Rankings based upon analysis of air quality data for the 21 candidate ozone episodes.

Rank	Score	Episode date
1	8	9 Jun 83 - 20 Jun 83
2	25	4 Jun 84 - 13 Jun 84
3	28	6 Aug 85 - 16 Aug 85
4	38	16 Jul 87 - 26 Jul 87
5	41	26 Jul 83 - 1 Aug 83
6	41	31 Aug 83 - 7 Sep 83
7	45	13 Aug 83 - 21 Aug 83
8	48	14 Jun 87 - 21 Jun 87
9	51	29 Jul 84 - 5 Aug 84
10	53	6 Jul 87 - 14 Jul 87
11	54	9 Jul 84 - 16 Jul 84
12	61	8 Sep 83 - 14 Sep 83
13	63	15 Jul 85 - 23 Jul 85
14	68	7 Jul 85 - 14 Jul 85
15	75	27 May 87 - 2 Jun 87
16	80	13 Aug 87 - 18 Aug 87
17	85	27 May 86 - 2 Jun 86
18	87	13 Sep 85 - 23 Sep 85
19	91	3 Jul 86 - 9 Jul 86
20	96	27 Jun 85 - 6 Jul 85
21	97	18 Jun 86 - 28 Jun 86

4. METEOROLOGICAL ANALYSIS

The top ten episodes identified from the objective ranking analysis plus the two 1980 episodes were selected for detailed meteorological analysis. The purpose of the meteorological analysis was to characterize objectively the transport flow regimes into and within the Northeast Corridor for each episode so that the rankings in Table 1 could be refined to reflect wind flow patterns corresponding to high ozone in the region. These patterns included the following: (1) along-corridor flow, (2) inter-urban recirculation within the Corridor, and (3) westerly flows into the Corridor. Climatologically it has been observed that these regimes are often associated with high ozone episodes in the Northeastern U.S (Vukovich and Fishman, 1986).

The meteorological analysis consisted of two parts. The first was designed to describe the daytime transport flows occurring <u>within</u> the Northeast Corridor. The second focused on the direction of transport <u>into</u> the Northeast Corridor.

The first part of the analysis included a review of surface weather maps and hourly reports from National Weather Service stations. It also included simulations of 3-day forward trajectories using the ATAD (Heffter, 1980) model for five Northeast Corridor cities. Synoptic flow conditions for each day with an observed ozone level above 0.12 ppm were classified according to one of seven synoptic regimes as noted in Table 2. An example of the surface weather conditions and synoptic regimes associated with the worst exceedance day (defined as the day with the most number of obbservations greater than 0.12 ppm during an episode) from the three episodes eventually chosen for ROM simulations are shown in Figure 2.

Table 2. Synoptic regimes for within corridor flows.

Regime	Description
1	Dominated by high pressure, weak flow mostly northerly (front side of high), no fronts near the corridor
2	Transition regime, high pressure along east coast, weak surface flow
3	High pressure off the east coast, along-corridor flow
4	Pre-frontal, along-corridor flow
5	Cold front or trough along east coast
6	Front between New York and Boston
7	Front south of New York or cyclonic conditions

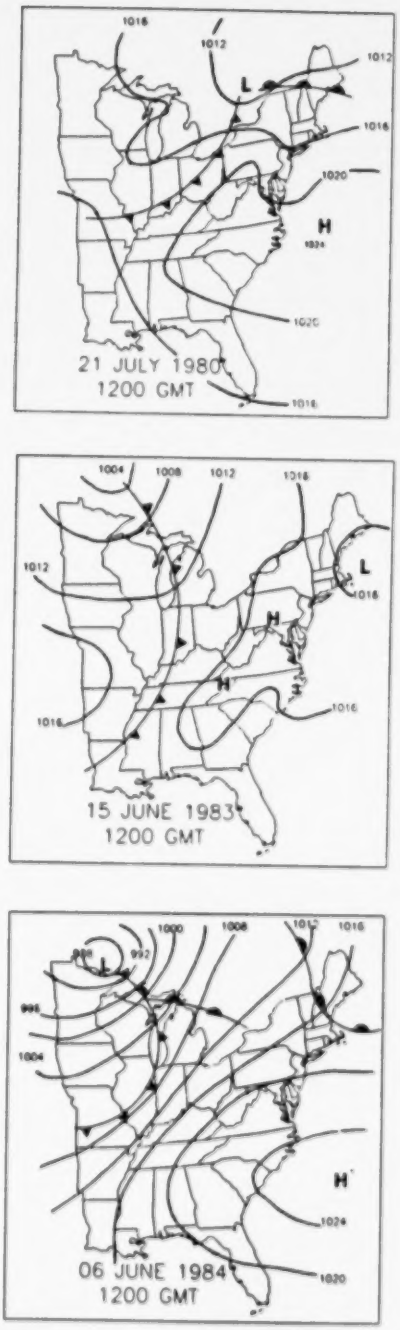

Fig. 2. Surface weather maps for the worst exceedance day from the top three episodes.

In the second part of the analysis, each exceedance day was classified according the one of four incoming flow regimes: (A) southwesterly (along-corridor), (B) westerly, (C) inter-urban recirculation, and (D) northwesterly. To accomplish this, 3-day ATAD backwards trajectories were constructed for five Northeast Corridor cities. Figure 3 shows the backward trajectories which were produced for the worst exceedance day in each of the three episodes eventually selected for ROM modeling.

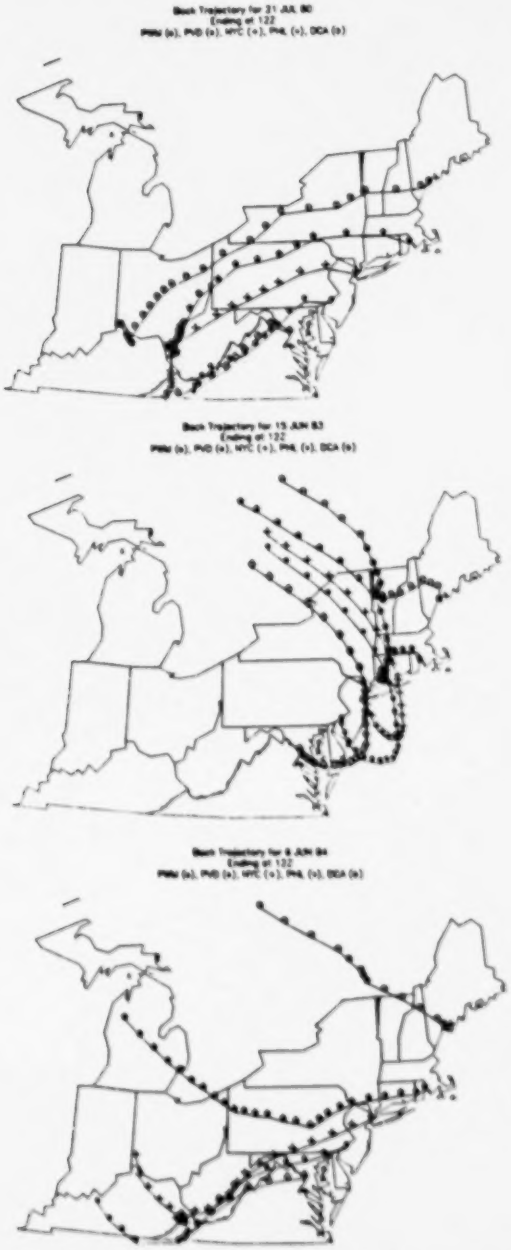

Fig. 3. Three-day ATAD back-trajectories ending on 1200 GMT on the worst exceedance day from each of the top three candidate episodes.

5. SELECTION OF EPISODES

The selection of the three episodes to be used for in-depth ROM simulation was based upon the objective air quality analysis and the frequency of days containing the priority flow regimes described previously. These were (1) along-corridor flow, (2) inter-urban recirculation, and (3) westerly flow into the corridor. Episode #1 (June 9-20, 1983) was found to contain multiday recirculation and inter-urban transport flow within the corridor. Episode #2 (June 4-13, 1984) was found to contain multiday westerly flows and thus perhaps the best meteorological potential for emissions outside the corridor to have an impact on ozone within the Northeast Corridor. However, high ozone episodes with several days of along-corridor flow were notably absent from the top ten episodes shown in Table 1. Examination of the 12-23 July 1980 episode showed that it contained several days of along-corridor flow, both at the surface and aloft. It also ranks among the highest five episodes based on air quality data.

Therefore, the three episodes containing the greatest frequency of the priority flow regimes and overall highest measured ozone concentrations within the Northeast Corridor from Washington, D.C., to southeastern Maine are as follows:

July 12-23, 1980
June 9-20, 1983
June 4-13, 1984

These three episodes have been selected as candidates to be used in the initial ROM simulations of emissions control strategies for the ROMNET project.

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